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TRANSACTIONS OF THE NEW YORK SURGICAL SOCIETY

Report of the Committee on the Study of the Pathology of the Stomach and Duodenum. 101

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The So-called Hot-Air Treatment of Painful and Partially Ankylosed Joints, and an Experimental Investigation of the Physiological Effect of the Local Application of Hot Air on General Metabolism.

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THE SO-CALLED HOT-AIR TREATMENT OF
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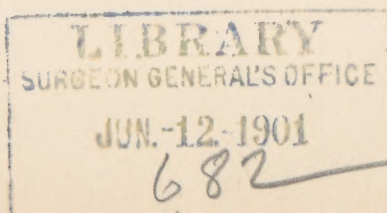
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SURGEON TO THE HOWARD HOSPITAL.

I. THE SO-CALLED HOT-AIR TREATMENT OF PAINFUL AND
PARTIALLY ANKYLOSED JOINTS.

THE use of heat as a therapeutic agent for the relief of pain is one which has been availed of for many centuries past, and therefore cannot claim any originality in the practice of the nineteenth century. Poultices, hot fomentations, hot water-bags, steam baths, etc., are only a few of the numerous ways in which heat is applied. In the Russian popular medicine we read that hot sand-baths have from time immemorial enjoyed a high reputation as a remedy for certain diseases.

The particular phase of this subject, to which our attention has been directed of late, is the use of dry air heated to as high a temperature as can be safely employed.

Apparatus.—The apparatus which has been employed in the series of cases given below is one which was constructed for me by Lentz & Sons, of Philadelphia. (Fig. 1.) It consists of a copper cylinder, attached to the bottom of which is a Russian iron fire-box containing a Bunsen burner,



extending the full length of the fire-box and projecting through one end to permit of attachment to gas-tubing. On one end of the cylinder is a large door, which can be instantly opened, and to the other end is attached a flexible sleeve of cloth, with a double draw-string, so that it can be drawn closely and firmly around the limb. The upper two-thirds of the cylinder are lined with sheet asbestos, the lower third

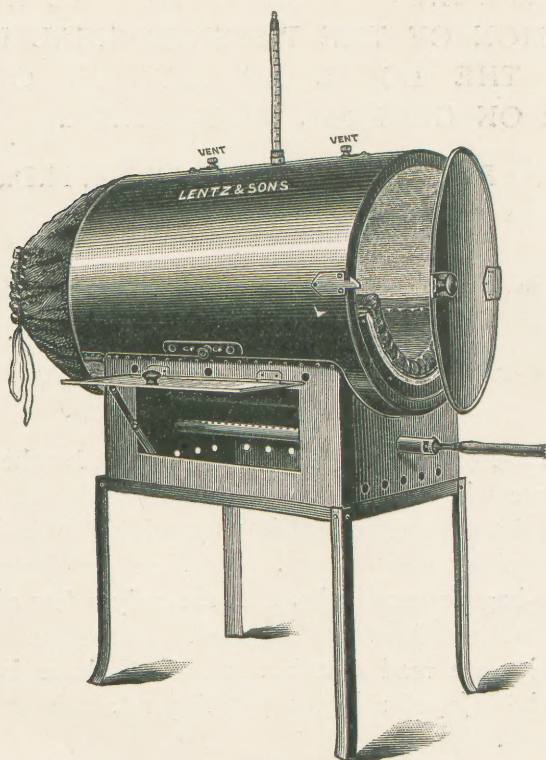


FIG. 1.—Frazier's apparatus for hot-air treatment.

is also lined with asbestos, but the latter is not attached directly to the cylinder, but is supported on three iron bars running the full length of the cylinder, and at a distance of about one and a half inches from it. On the cradle rests a very thick piece of magnesia. This material I found, from its non-conduction of heat, to be the most suitable, as the

limb could rest directly on it without the slightest danger of sustaining a burn. At the sides and top of the cylinder are small openings which insure free circulation of air, and thus prevent any accumulation of moist air within the cylinder.

The apparatus was constructed for the Out-Patient Department of the University Hospital, where some three hundred baths were given to test its efficiency. It was found to be most satisfactory, and we can justly claim for it many good features.

The required temperature can be obtained quickly in from ten to fifteen minutes; the ventilators at side and top prevent the accumulation of moist air, which, if present, would subject the patient to the risk of being burned; the large door at the end enables one, by opening it, to promptly reduce the temperature, if it is so desired; and, finally, it is substantially but simply constructed, and involves nothing that can get out of order or require repair.

The cases that were treated included acute and chronic articular rheumatism, gonorrhœal rheumatism, gout, traumatic arthritis, synovitis, tenosynovitis, and fibrous ankylosis.

Technique.—The routine employed in administering the bath was as follows: The patient's pulse and temperature were first taken and recorded. The limb, first being completely enveloped with a piece of lint, which was wrapped loosely about the part, was then placed in the cylinder. The time allowed for each bath was from three-fourths of an hour to an hour. At intervals of every twenty minutes the door of the cylinder was thrown open momentarily to allow of the ingress of a fresh supply of air. If the patient perspired freely this opportunity was taken advantage of to wipe the limb thoroughly dry. If this precaution is not taken, and the limb is allowed to remain bathed with sweat, there is possibility, if the temperature be exceedingly high, of a superficial burn resulting. This happened in several cases where the precaution was not taken. The degree of temperature that was employed varied; some patients bearing with per-

fect comfort a degree of heat which would be extremely painful to others. The average was about 300 degrees, although in one case the temperature reached 375 degrees, to which the patient seemed quite indifferent. The frequency with which the baths were given varied with the severity of the case, usually, however, they were administered on every other day.

The physiologic effect of heat has been carefully studied by the writer, and the results arrived at are embodied in a later portion of the present paper.

From our knowledge of this physiologic action of heat, can we draw any conclusions as to how these joint-affections should be theoretically benefited? To do this intelligently we should have a clear picture in our minds of the general morbid anatomy of these joint-affections, and for convenience we may adopt a classification which divides them into (1) those of rheumatic origin, (2) those of tubercular origin, and (3) those of traumatic origin. The lesions to be found in the subacute or chronic rheumatic joints may be briefly described as follows: The synovial membrane, the ligaments, the cartilages, and the periarticular structures are all or only in part involved, according to the gravity and chronicity of the particular case. The synovial membrane is usually thickened and slightly injected. Little fluid exists in the joint, except during an exacerbation. The fibrous capsule and ligaments become thickened, dense, and stiffened by hyperplasia, and sometimes the adjacent tendons and their sheaths, the fascia and aponeuroses undergo similar alteration, so that the movements of the joints become seriously interfered with. The cartilages are often rough and occasionally present erosions, which are either naked or covered with a layer of newly formed connective tissue. This may occasionally produce fibrous adhesions between the articular surfaces. This is a brief description of what we have to deal with in a rheumatic joint.

We pass on now to the pathology of the tubercular joint. The periarticular structures, ligaments, and synovial

membrane may all be attacked by this morbid process. If the synovial membrane is involved, it becomes covered with the infected granulation tissue which may extend to the capsule or surrounding structures. The parts become œdematous and gelatinous, and the joint-cavity itself contains either little or no fluid, or may be distended with a profuse serous effusion. The tissues of the joint are usually highly vascular.

In the case of the traumatic joint, we find in the chronic form the articular structures thickened with a plastic exudate, and afterwards with the newly formed fibrous tissue. Adhesions, the result of blood-clots or an exudation, form and bind together the folds of synovial membrane or articular surfaces. There may be a large effusion in the joint, or the effused fluid may have been entirely absorbed.

Here, now, in a concise form we have presented the factors that we have to deal with and the obstacles to be encountered in attempting to remove these pathological elements, and to restore to the joint normal functional activity.

We turn our attention now for a moment to what actually takes place when a joint is subjected to a temperature of 300° F., or thereabouts, for a period of an hour. In the first place, when the limb is removed from the apparatus we can plainly see a diffuse hyperæmia of the integument, indicative of a dilatation of the capillaries and arterioles therein. The patient himself will tell you that the part feels numb, a phenomenon due, no doubt, to the action of the heat on the superficial sensory nerve-filaments. The body temperature of the patient will be about $\frac{1}{2}^{\circ}$ to 1° elevated above normal, and the pulse will increase in frequency from 10 to 20 beats per minute, which of itself suggests the possibility of an increased blood-supply to the affected limb. The patient will also inform you that he, provided the joint be not ankylosed, experiences less pain and more freedom in the movements of the joint, the former fact explained perhaps by the anæsthetic effect of the heat on the nerve-supply of the articular structures. These clinical facts can be obtained by a gross observation on the part of patient and physician.

From the experimental observations referred to above we learned that certain physiological phenomena followed the application of heat, such as increased arterial tension, elevation of blood-pressure, dilatation of the lumen of the blood-vessels, diminution of the erythrocytes, decrease of hæmoglobin, increase in the elimination of nitrogen, increase in frequency of the heart's action, and, in the experiments on our own patients, a distinct retention of nitrogen.

Such are the clinical and physiological phenomena that we must employ in attempting to explain the influence of hot air on the pathological lesions that confront us.

In those cases in which there is a diathesis, either rheumatic or tubercular, we can comprehend no theory, and will discard at once any suspicion that this treatment could have any beneficial constitutional effect. So we must devote our energies to the discussion of the purely local influence. When we have tissues swollen and infiltrated with plastic exudate, as in rheumatic and traumatic joints, and we increase the lumen of the vessels, both veins and arteries, increase the blood-pressure and the frequency of the pulse, do everything, in fact, to increase the blood-supply, we are employing a method—are we not?—which should surely be instrumental in carrying off that exudate and in allowing the part to return to its normal state. Soon, however, this exudate becomes organized, both in the normal structures of the joints themselves as well as in the plastic bands or adhesions that have been thrown across, from one articular surface to another, rendering the capsule and ligaments less yielding, and thus, with the aid of the adhesions, limiting the movements of the joint. Later this newly formed connective tissue contracts, presses on the blood-vessels, and diminishes the blood-supply of the tissues involved. In these structures, so altered, a very much improved circulation might produce a temporary cedema, which would, to carry the idea still further, permit of a certain amount of mechanical stretching, and thus explain the improvement in motion that has been shown to follow.

As regards the relief of pain that has been noted, two explanations suggest themselves. One that the exudate, both around and possibly in the sheaths of the nerves themselves, is responsible by its presence for the pain, and when this exudate is all or in part removed the pain is correspondingly diminished. Another explanation is that the high temperature has an anæsthetic effect on the nerve-filaments themselves. This would account for the clinical observation that in some cases the relief from pain is only temporary, and after the lapse of an hour or so, when this anæsthetic effect has spent itself, the pain returns.

There are some cases that present themselves to us where the articular structures have undergone little or no pathological changes, and where we have purely the synovial effusion to deal with, an effusion composed chiefly of synovial fluid, but at times partially of blood and blood-clots, which, allowed to remain, may organize and form troublesome adhesions. Can we hasten the absorption of this fluid by the local action of the hot air? If our hypothesis be true, if dilatation of the blood-vessels does take place, and the vessels open their mouths, figuratively speaking, for the reception of the fluid; and if, too, as we have been led to assume, the lymphatic circulation is stimulated to more vigorous action, naturally, we are led to accept this method of treating an effusion as being at least a rational one. To my mind, the case is somewhat parallel to what happens after the removal, from an œdematous arm or leg, of an Esmarch bandage, which has been allowed to remain on the limb about ten minutes. What is a serious objection to employing Esmarch bandages in amputations — reactionary hæmorrhage — is converted into a distinct benefit in the swollen limb,—the stimulated circulation carrying away and flushing out the fluid that lies stagnant in the tissues. So we could go on applying the same line of reasoning to the effusion into the sheath of a tendon, as in tenosynovitis, as well as to that occurring in the synovial sac.

What of the tubercular joints, where the pathological

changes are due originally to an infectious material, and we have formed there, in many cases at least, infectious granulation tissue. Underlying the local lesion is the force of an inherited diathesis, which predisposed to the original attack, and acts as a constant barrier to the tissues regaining their normal vitality. In these cases it would be fruitless to search for a theory according to which benefits might accrue from the external application of hot air. That is to say, we believe that this treatment could have no curative effect on the specific lesions. After the active process has subsided and there remains behind troublesome adhesions, which cause more or less ankylosis, then, of course, we may expect some beneficial results, just as we would in an ankylosed joint, the sequel of any other affection. In the series of cases recorded below are four reported by V. P. Gibney,¹ of New York, which correspond exactly to the type we have just described,—namely, ankylosis following tuberculous affections.

Conclusions.—How much we ought to expect from this remedy is, after all, the practical side of the question. Ought we to look for any permanent results (or such brilliant results as have been reported by others) in treating a joint whose structures have been perverted by such constitutional diseases as gout, rheumatism, or tuberculosis? Do we not aim in gout and rheumatism to increase nitrogen elimination? Should we then reverse our methods, and resort to one which dams the nitrogen up in the system? The question is easily answered, for we can advance no theory to explain a possible beneficial result when such a physiological phenomenon, as has been proved, confronts us. As for the germs of tuberculosis, they are most fertile where a highly vascular soil is provided for their growth, therefore we claim for this treatment no specific virtues that would warrant its use in these cases.

Gonorrhœal rheumatism, which so stubbornly responds to present methods of treatment, can hope for little more than the one just under discussion. The symptoms are kindled by the bacteria or their toxines, and while the latter

continue to be absorbed and keep alive the morbid changes in the articular and periarticular structures, no positive results should be anticipated. When the gonorrhœa itself has been cured and the activity of the morbid process subsides, and we are confronted with a joint crippled in its movements by bands of adhesions, in these cases we may rightly and reasonably expect that the adhesion can more readily be broken up and the function of the joint restored by the hot-air treatment.

Permanent cures of local lesions, symptomatic of diathetic diseases, let me repeat myself for emphasis' sake, are not to be looked for in the employment of hot-air baths. So much we can safely and positively assert without exciting any antagonism.

Excluding that large percentage of joint affections, there is left us only those of traumatic origin. For the relief of these, I claim, we have a most useful and sometimes indispensable method of treatment, and the results which we obtain can be called permanent, for when once the joint is restored to its normal functional activity, we have no latent flame of an inherent or acquired diathesis to kindle anew the inflammatory process.

I should not hesitate to recommend it in the treatment of the sequelæ of any joint injuries which have proved intractable to the more commonplace remedies. And in using it I should advise that it be employed as an adjuvant to the others, massage, passive motion, and the like, and you will find by calling all these to your assistance you have resorted to a method of treatment which will yield eminently satisfactory results. Shall we employ it in the treatment of rheumatism at all? Such a question may seem to some at first sight startling, when it is remembered that the original English apparatus was constructed chiefly for the treatment of this malady and the results it has reported to have attained seemed to follow almost like magic. To be conservative, however, I think, there is a certain field for its use,—namely, in these cases where internal remedies and local application

have failed to relieve the pain. Here, it seems to me, and my views are corroborated by others, we should use it, and the patient will surely be afforded temporary relief. In closing, I may say that I have employed the hot-air baths in a large and varied number of cases (abstracts of which are given below) purely from an empirical stand-point, and in drawing these conclusions it has been my aim to be as conservative as possible.

On glancing over the reports it will be seen that in some the good effects were permanent, in some they were temporary, and in others the results were negative.

CASE I. *Fibrous Ankylosis of the Metacarpal and Phalangeal Joints of Left Hand, due to Bullet-Wound of Hand, followed by Prolonged Fixation on Splints.*—There was extensive infiltration of lymph in the periarticular structures and around the sheaths of the tendons. This lymph had become wholly or partially organized, so that there was absolute immobility of all the joints of the hand. Number of treatments, nineteen. Result: Patient was able to almost completely flex all the fingers, and was enabled to resume his occupation as a farm-hand. Massage and passive motion, attempted before the treatment, had utterly failed.

CASE II. *Ankylosis of Thumb from Long-Continued Use of Splint.* Number of treatments, nineteen. Result: Function of thumb completely restored.

CASE III. *Tenosynovitis of Tendon Patellæ resulting from an Injury received about One Year Ago.*—Patient complained of pain when making any motion that called the tendon into play. Number of treatments, ten. Result: Complete disappearance of pain.

CASE IV. *Fibrous Ankylosis of Elbow following Fracture of Internal Condyle Two Months Ago.*—Radiograph taken showed that there was no outgrowth of callus to interfere with the articular functions. The joint was ankylosed at a right angle and was absolutely immovable. Number of treatments, twelve. There was a gradual return of motion while the patient was under treatment. He became discouraged, however, at the slow progress he was making and discontinued coming to the clinic. There was every reason to hope, in this case, for a useful limb.

CASE V. *Ankylosis of Elbow*.—This case is of a nature similar to the preceding one, but not so pronounced. Young mechanic sustained fracture of elbow-joint some months ago. Pronation and supination of the forearm were quite possible, but arm could not be flexed beyond angle of 90 degrees, and extension was very incomplete. An outgrowth of callus at the anterior articular end of humerus, beautifully demonstrated by the radiograph, explained the limit of motion in the direction of flexion, but the limited extension was evidently due to fibrous adhesions. Number of treatments, three. Result: It was possible with very little force to completely extend forearm on arm.

CASE VI. *Ankylosis of Knee*.—The patient gave a history dating back some years, of repeated inflammatory attacks of an unknown nature in the knee-joint, and presented himself with a joint which now admitted of very little flexion. Even employing much force one is not able to break up the adhesions that limit motion in the joint. After he had been given three baths, there being no sign of improvement, the treatment was discontinued.

CASE VII. *Disability following Colles's Fracture, sustained Six Weeks Ago, and Wrist-Joint Painful and limited in Motion*.—Number of treatments, four. Result: The pain was relieved and the function of the joint restored.

CASE VIII. *Acute Synovitis of the Wrist-Joint following a so-called Sprain*.—Two days after the injury was received, the wrist being then swollen and painful, the hot-air treatment was begun with gratifying results. After four baths the patient was discharged, all the symptoms having been relieved.

CASE IX.—This was a case resembling very much the preceding as to the nature of the injury and the results obtained.

CASE X. *Acute Synovitis of the Knee-Joint, which was Excessively Painful and very much distended with Synovial Fluid*.—The limb was placed in the hot-air apparatus and retained there for three-quarters of an hour, at the end of which time the joint could be flexed beyond a right-angle without eliciting but comparatively trifling pain. During the succeeding afternoon and night the patient suffered intensely, and on the following day, feeling in no way benefited by the treatment, it was discontinued.

CASE XI. *Chronic Synovitis and Partial Ankylosis of Ankle-Joint, the Result of an Injury sustained Three Months Before*.—The tissues of the part were quite cedematous. Ten hot-air baths

were given, at the end of which time the normal nature of the joint was partially restored; pain was very much relieved, and the patient, who had previously been treated by the usual remedies without improvement, was able now to resume his occupation as a carpenter.

CASE XII. *Chronic Synovitis of the Wrist-Joint of Traumatic Origin, the Joint-Capsule being somewhat thickened and distended with Synovial Fluid.*—The patient was incapacitated for work. The patient received nine baths, and after which was able to resume his occupation. He expressed great confidence in the efficiency of the treatment.

CASE XIII.—The nature of this injury corresponded quite closely with that just cited above, differing, however, only in the fact that the symptoms were more marked and of longer standing. The result in this case, after the use of ten baths, was not so gratifying. The restoration of the function of the joint was only partial when the patient discontinued his visits to the clinic. Perhaps a continuance of the treatment might have yielded better results.

CASE XIV.—This patient, an athlete, who was training for short-distance running, presented himself with a *chronic tenosynovitis of the extensor tendons of the leg* which handicapped him very much in his attempts at attaining high speed. Rest and counter-irritation had already been given a fair trial, but without success. He paid fifteen visits to the clinic for treatment and was then discharged, as he appeared to be entirely relieved. Whether there was a recurrence of the pain, on resuming his exercise, I have not been informed.

CASE XV. *Periarthritis of Metacarpo-Phalangeal Joint caused by the Hand being caught between Two Dumb-Bells.*—The patient, referred to me by Dr. J. William White, an artist by profession, was seriously hampered in his work by the injury. He was under observation for a week, during which time he used the hot-air bath four times, and expressed himself as being then somewhat improved. The treatment was continued at the patient's home, with what result is not known.

CASE XVI.—The lesion in this case was similar to the one just described. Four baths were given. Result: Slight improvement,—that is to say, the pain was somewhat relieved and joint more supple.

CASE XVII. *Gonorrhæal Rheumatism affecting both Wrists and both Knees.*—Particular attention was paid to this patient, in that he was suffering from a disease in which the usual form of treatment yields far from brilliant results in a great number of cases. The joints were subjected to the hot-air bath fifteen times, the patient at the same time receiving internal medication and urethral irrigation. Owing to this fact the intrinsic value of the hot-air baths cannot be definitely estimated. On glancing over the notes of this case I find that during the treatment the pain diminished in severity, the swollen joints decreased in size, and their functional activity improved. The results were by no means startling, however, nor was recovery by any means complete, a certain amount of pain and stiffness continuing. This much may be claimed for the treatment,—namely, that pain being in this case a prominent symptom, the patient was made comparatively comfortable. Inasmuch as the urethritis still persisted, it could hardly be expected that any form of treatment applied to the joints would be permanent in its effects.

CASE XVIII.—In this case we have the only case of *gout* that presented itself at the clinic. The patient, a painter, referred to the clinic by Dr. S. W. Morton, had suffered for some time with gout, which had so crippled him that he had been unable for a year or more to pursue his occupation. The results in this case were most gratifying. After three treatments the patient was able to walk to and from the clinic, a distance of some four miles, with comparative ease. This he had not been able to do for nine months. Thirteen baths in all were given, in the mean time the patient receiving no internal medication. He was so much benefited by this time that he discontinued his visits, and I learn from Dr. Morton that at the present time, some three months having elapsed, he is now following his occupation.

CASE XIX.—Margaret M., aged thirty-one years, presented herself with an *acute articular rheumatism of the middle phalangeal joint of ring-finger*, she having had previous attacks in other joints of the body. The joint in question was swollen and so extremely painful as to incapacitate her from work. The patient received some fifteen baths, at the end of which time, although the joint had not returned to its normal size, it was entirely free from pain, and she was again able to resume her occupation with perfect comfort.

CASE XX.—Edward G., aged thirty-eight years, a patient in the Medical Ward of the University Hospital, was referred to this department with *chronic articular rheumatism of both elbow- and wrist-joints*, of four years' standing. The hot-air treatment was persevered with for some time, the patient receiving twenty-one baths. In this case the permanent effect was practically *nil*. He experienced some freedom from pain and slightly increased mobility in the affected joints immediately after the baths, but the good effects soon vanished.

CASE XXI.—Mrs. G., aged seventy years, was referred to me from the Medical Dispensary, suffering with *subacute rheumatism of the knee*. The attack had lasted for about three weeks. After five baths the patient claimed to be able to go about with comparative ease. She then discontinued her visits.

CASE XXII.—James M., a coachman, referred to the clinic by Dr. J. W. Dick, has suffered for the past few months with *rheumatism*, almost every large joint of the body having been involved at one time or another. When first seen by us the ankle-joints were the chief offenders. Pain and stiffness were so marked that it was out of the question for him to attempt following his occupation. The improvement, if any, was so slight that after the seventh bath the treatment was discontinued.

CASE XXIII.—William S., a laborer, suffering with *rheumatic arthritis*, was admitted to the hospital with an extremely painful and practically useless shoulder-joint. The patient was so completely crippled in this joint that every effort was made towards alleviating the symptoms, and thus testing the efficiency of the treatment. The patient received eleven baths in eleven consecutive days, at the end of which time he was discharged from the hospital, with instructions to report at the end of a week. Certain it was that, on leaving the hospital, he had much more motion in the joint and much less pain, but on his return, he had relapsed into his previous state, none the better for the attention he had received.

CASE XXIV.—Miss R. came to the clinic from Ebensburg, Pa., with *chronic articular rheumatism of both elbows*. The right arm was but slightly affected, but the left so much so that she was forced to discontinue her work as a stenographer. The left joint was almost completely ankylosed midway between flexion and extension. The pain was intense, not only in attempts to

practise passive motion, but also when the joint was entirely passive. During the preceding six months internal medication had been tried and failed. As a last resort, she sought relief in the hot-air bath. She took thirty of the baths, during which time she showed signs of gradual improvement. At least she spent no more sleepless nights; she was able to feed herself with her left hand and arrange her back hair, a crucial test with women of return of function to the elbow-joint. It might be mentioned that during the course of the treatment massage was prescribed, but, being followed by a distinct relapse, was discontinued. The patient is now able to resume her occupation, although the joints have by no means returned to their normal state, and there is no assurance that, should the treatment be discontinued, the improvement would cease to continue. Iodide of potassium was administered internally.

CASE XXV.—Disability of shoulder due to a severe contusion, the injury having been sustained simultaneously with a fracture of the outer end of the clavicle. Union of the bone occurred in due time, but the function of the joint remained very much impaired. The general course of treatment had been massage and gymnastic exercise. In order to expedite matters it was decided to employ the hot-air baths. The patient, a physician, and therefore qualified to express an intelligent opinion, wrote me as follows: "There has been material improvement in the range of motion in my shoulder-joint the past two or three weeks, and I feel that I can attribute a not unimportant part of this to the several hot-air baths, etc."

Cases reported by V. P. Gibney,² of New York.

CASE I. was one of firm fibrous ankylosis after tuberculous ostitis of the knee. The patient had seven baths, the highest temperature of which was 280° F. As a result of the treatment, the patient has been able to do without apparatus and to use his limbs, the motion of which has become much easier and has increased 20 degrees.

CASE II. was one of fibrous ankylosis in a tuberculous knee. This patient received six baths. The knee has gained 12 degrees of motion, and there has been no pain.

CASE III. was one of ankylosis from a deformed knee, the result of tuberculous disease. In this patient adhesions had been broken up under the use of nitrous oxide. As a result of this

operation the patient experienced excessive pain. The limb was at once put into the bath, and in ten minutes the pain was relieved.

CASE IV. was one of a stiff and painful hip following tuberculous disease. After three baths the patient has less dread and apprehension in testing his limb and the steps are taken with more security.

II. THE PHYSIOLOGICAL EFFECT OF THE LOCAL APPLICATION OF HOT AIR ON GENERAL METABOLISM.

[*From the Pepper Laboratory of Clinical Medicine, No. 11.*]

The physiological effect of heat has been the subject of much work both in the clinic and laboratory. Nikolai and Parewsky studied the therapeutic and physiological effect of hot sand-baths on twenty-eight rheumatic soldiers in Russia. These patients were stripped to the skin and covered from head to foot with heated sand. Each bath lasted one-half hour. The results of their investigations may be briefly summed up as follows:

(1) The axillary temperature invariably rises,—average 0.53° C.

(2) Pulse becomes accelerated,—average increase 8.6 per minute.

(3) Respiration becomes accelerated,—average increase 3.4 per minute.

(4) Total loss of weight,—averaged 1.84 Russian pounds.

(5) Blood-pressure becomes elevated.

(6) On the whole, they most decidedly deserve an extensive employment for therapeutic purposes.

Dr. N. P. Belakovsky³ experimented on healthy young men to study the biological effect of local arenation. Temperature of bath, 55° C.; time of bath, one hour. The following conclusions are drawn:

(1) General bodily temperature always sinks.

(2) Cutaneous temperature of limb constantly marked by rises.

(3) Frequency of pulse always somewhat augmented. (In the case of the arm, the average increase was equal to 5.60; in the case of the hip, the average increase was equal to 5.40.)

(4) Respiration remains apparently unaffected, and arterial tension is more or less markedly elevated. (Average rise equalled 17.4 millimetres. Hg.)

(5) Elasticity of integument is increased.

(6) Tactile sensibility is increased.

(7) Body weight distinctly sinks.

The effect on metabolism, of an elevation of temperature, artificially produced, has been the subject of investigation by Simanowsky,⁴ who experimented with dogs. Simanowsky concludes that there was no increase in the elimination of nitrogen, through the urine in these cases, in contradistinction to the increased output, which is a characteristic and almost constant manifestation in fever.

Richter,⁵ on the other hand, found in his experiments on dogs, in the same manner as Simanowsky, that there was a distinct increase in the output of nitrogen, demonstrated in the twenty-four hours subsequent to the treatment, but completely disappearing on the second day. There thus is seen to exist a disagreement between the results of these two investigators.

Several observations have been made on the effect of excessive temperature, artificially produced, on the circulatory system.

Werhowsky⁶ found, in certain experiments on dogs, that the effect of this excessive temperature was a reduction in hæmoglobin and a diminution of the erythrocytes.

Subjected to a temperature of 44° C. for more than an hour, Maurel found that the leucocytes lost their amœboid movement.

Cyon⁷ found that a sudden elevation of temperature of the blood, streaming through the cerebral vessels, slowed the action of the heart by stimulating the vagus.

The influence on the heart itself was the subject of study

by Cyon, who determined that there was a pronounced acceleration and weakening of the cardiac contractions, both in systole and diastole. On the blood-vessels themselves, the effect of the application of heat is a dilatation of the lumen of both arteries, veins, and capillaries.

My own observations on the physiological aspect of this subject were made in connection with twenty-five cases that were treated by the hot-air method in the Out-Patient Department of the University Hospital. These cases included acute and chronic articular rheumatism, gonorrhœal rheumatism, gout, traumatic arthritis, synovitis, tenosynovitis, and fibrous ankylosis. The following phenomena were noted after the limb, either arm or leg, as the case might be, was removed from the apparatus, having been subjected to a temperature of about 330° F. for an hour. In the first place, there were noticed irregular erythematous patches and a certain amount of local anæsthesia, the patients complaining usually that the part felt numb. The general bodily temperature was slightly elevated, and there was an increase in the rate of the pulse. The following is a table of cases picked at random from the records illustrative of these two phenomena:

TABLE I.

Diagnosis.	Time of Bath.	Average Temperature.	PULSE.		TEMPERATURE.	
			Before Bath.	After Bath.	Before Bath.	After Bath.
Rheumatic arthritis of shoulder	1 ¼ hrs.	318°	80	96	99°	99 $\frac{4}{5}$ °
Ankylosis from Colles's fracture	1 hr.	321°	92	100	99°	99 $\frac{2}{5}$ °
Gonorrhœal arthritis of knees	"	307°	92	100	99 $\frac{4}{5}$ °	100 $\frac{1}{5}$ °
Rheumatic arthritis of elbow	"	322°	80	88	98 $\frac{4}{5}$ °	99 $\frac{2}{5}$ °
Ankylosis of fingers	"	343°	80	88	99°	99 $\frac{2}{5}$ °
Gonorrhœal arthritis of wrist-joints	"	344°	116	120	99 $\frac{4}{5}$ °	100°

The maximum increase in the rate of the pulse was 16, and the maximum elevation of temperature four-fifths of a degree.

The cases on which I studied the effect of hot air on metabolism included three in all, one suffering with gout, one with rheumatic arthritis of the shoulder, and one with traumatic synovitis of the wrist-joint. The experiments were conducted in the Pepper Laboratory of Clinical Medicine, as follows:

The patients were placed in bed on a constant diet, which is contained in the following table, showing approximately the amounts of the several constituents:

TABLE II.

Articles.	Quantity.	Nitrogen.	Fat.	Carbohydrate.
Milk	1750 cubic centimetres.	8.75	52.5	78.75
Bread	300 grammes.	3.8	3.0	180.0
Egg	One.	0.9	4.4	. . . . .
Butter	50 grammes.	0.1	45.0	. . . . .
Sugar	50 "	. . . . .	. . . . .	40.0
Tea	Two cups.	. . . . .	. . . . .	. . . . .
Total		13.55	104.9	298.75

60 grammes milk sugar = 252.10 calories.
 84.68 " albumen = 347.18 "
 104.9 " fat = 996.55 "
 298.75 " carbohydrate = 1254.75 "
 2650.48 = total calories.

This diet was selected as being sufficient for an adult male in a condition of health.

The experiments then proceeded as follows: daily estimations were made of the samples of food containing nitrogen, and also of the excretions, both urine and fæces. This was continued until a nitrogen balance was obtained. When this occurred the patients were given hot-air baths, in some cases of the arm and in others of the leg, one daily, lasting one hour; the temperature averaging about 300° F. The patients, except during the time the baths were being administered, remained in bed.

This is a general outline of the manner in which the experiments were conducted.

In the week preceding the baths the patients gained in

weight on the diet that was allowed them,—*e.g.*, in one case the patient weighing on admission one hundred and thirty-four pounds, and at the end of the week one hundred and thirty-seven pounds. The amount of urine excreted in the week preceding the baths is given in the table below.

TABLE III.

Day.	Case I.	Case II.
First	1830 cubic centimetres.	1935 cubic centimetres.
Second	1310 " "	2425 " "
Third	1030 " "	1770 " "
Fourth	1180 " "	1575 " "
Fifth	1135 " "	1730 " "
Sixth	1305 " "	1485 " "
Seventh	1380 " "	1165 " "

During the period of hot-air baths the amount of urine diminished greatly; the average amount passed before the baths being 1310 cubic centimetres, and the average amount during the baths 835 cubic centimetres.

Figures for the individual cases, cited in Table II, are as follows:

TABLE IV.

Day.	Twenty-four hrs.	Case I.	Case II.
First . .	Total amount	980 cubic centimetres.	885 cubic centimetres.
Second .	" "	765 " "	880 " "
Third . .	" "	690 " "	517 " "
Fourth .	" "	800 " "	595 " "
Fifth . .	" "	955 " "	1045 " "
Sixth . .	" "	820 " "	530 " "
Seventh .	" "	. . . . .	580 " "

The explanation of this is not difficult to determine, the copious sweating furnishing ample cause for such reduction. It may be that increased respiratory evaporations also played a part, and disturbances of circulation may also have contributed. The decided loss in body weight, in spite of the distinct nitrogen retention, to which reference will be made below, is demonstrative evidence of the fact that there was no water retention. The loss of weight coincident with the

nitrogen retention might at first sight seem striking, but is abundantly explained by the profuse sweating caused by the baths. The figures of the case above quoted, showing a gain of weight before the baths, are equally pronounced in demonstrating the loss of weight during the baths.

Weight of patient on first day of baths 137 pounds;
weight of patient on last day of baths 134 pounds.

In all of the cases careful analyses were made of the food administered and of the fæces and urine, the Kjeldahl method being employed. The nitrogen balance was readily obtained and the conditions maintained as nearly as possible after the baths were instituted. Unfortunately, it was discovered that the diet was not strictly observed by the first two patients, and some of the dejecta were lost during the night, so that the figures are valueless except so far as they could be compared with those of the third case, in which every detail was rigidly enforced. The difficulty of controlling patients (practically well in their general physical health) in bed and on a reduced and uniform diet will be appreciated fully by those only who have undertaken studies of metabolism.

It will be noted from the table below that a balance was practically established on the sixth day, the input and output being practically equal with free urination. On the seventh day for some reason the amount of urine fell off considerably, and there was a retention of nitrogen; but the equality was again approximated on the eighth day, after which the baths were instituted.

The following figures were obtained in Case III:

TABLE V.

Day.	Diet.	Nitrogen.	Excretion.	Nitrogen.	Balance.
First.	Milk	11.0250	Urine (1935 cubic centimetres) Fæces (average per day)	16.660 0.6504	
	Bread	4.2780			
	Egg	1.0455			
	Butter	0.0825			
Total . .		16.431	Total . . .		17.3104 + 0.8794

TABLE V.—*Continued.*

Day.	Diet.	Nitrogen.	Excretion.	Nitrogen.	Balance.
Second.	Milk	11.6375	Urine (2425 cubic centimetres) Fæces (average per day)	21.8977 0.6504	
	Bread	4.2780			
	Egg	1.0293			
	Butter	0.0825			
Total . . . 17.0273			Total . . . 22.5481 + 5.4208		
Third.	Milk	10.2660	Urine (1770 cubic centimetres) Fæces (average per day)	19.204 0.6504	
	Bread	4.2780			
	Egg	1.0620			
	Butter	0.0825			
Total . . . 15.6595			Total . . . 19.8544 + 4.1939		
Fourth.	Milk	9.1875	Urine (1575 cubic centimetres) Fæces (average per day)	18.9630 0.6504	
	Bread	4.278			
	Egg	0.8509			
	Butter	0.8325			
Total . . . 14.5939			Total . . . 19.6134 + 5.0195		
Fifth.	Milk	10.2375	Urine (1730 cubic centimetres) Fæces (average per day)	20.555 0.6504	
	Bread	4.2780			
	Egg	1.0293			
	Butter	0.0825			
Total . . . 15.6273			Total . . . 21.2054 + 5.5787		
Sixth.	Milk	9.2400	Urine (1485 cubic centimetres) Fæces (average per day)	13.8255 0.6504	
	Bread	4.2780			
	Egg	1.0096			
	Butter	0.0825			
Total . . . 14.607			Total . . . 14.475 — 0.1320		
Seventh.	Milk	11.6375	Urine (995 cubic centimetres) Fæces (average per day)	10.8654 0.6504	
	Bread	4.2780			
	Egg	0.9415			
	Butter	0.0825			
Total . . . 16.9395			Total . . . 11.5158 — 5.4237		
Eighth.	Milk	10.2562	Urine (1185 cubic centimetres) Fæces (average per day)	12.8849 0.6504	
	Bread	4.2780			
	Egg	1.0928			
	Butter	0.0825			
Total . . . 15.709			Total . . . 13.5353 — 2.17373		

TABLE V.—*Concluded.*

Day.	Diet.	Nitrogen.	Excretion.	Nitrogen.	Balance.
Bath 1. Ninth.	Milk Bread Egg Butter	10.2562 4.278 1.0840 0.0825	Urine (885 cubic centimetres) Fæces (average per day)	11.2130 0.7426	
Total . . . 15.7007			Total . . . 11.9556 — 3.7451		
Bath 2. Tenth.	Milk Bread Egg Butter	10.4210 4.2780 0.9460 0.0825	Urine (880 cubic centimetres) Fæces (average per day)	12.1968 0.7426	
Total . . . 15.7185			Total . . . 12.9394 — 2.1737		
Bath 3. Eleventh.	Milk Bread Egg Butter	9.1875 4.2780 0.9920 0.0825	Urine (517 cubic centimetres) Fæces (average per day)	8.2668 0.7426	
Total . . . 14.5400			Total . . . 9.0094 — 5.5306		
Bath 4. Twelfth.	Milk Bread Egg Butter	9.4937 4.2780 1.1060 0.0825	Urine (559 cubic centimetres) Fæces (average per day)	9.1211 0.7426	
Total . . . 14.9602			Total . . . 9.8637 — 5.0965		
Bath 5. Thirteenth.	Milk Bread Egg Butter	9.1875 4.2780 0.9767 0.0825	Urine (1045 cubic centimetres) Fæces (average per day)	15.5440 0.7426	
Total . . . 14.5247			Total . . . 16.2866 + 1.7619		
Bath 6. Fourteenth.	Milk Bread Egg Butter	9.4937 4.2780 1.0254 0.0825	Urine (530 cubic centimetres) Fæces (average per day)	7.7910 0.7426	
Total . . . 14.8796			Total . . . 8.9336 — 6.3460		
Bath 7. Fifteenth.	Milk Bread Egg Butter	9.1875 4.2780 1.0280 0.0825	Urine (580 cubic centimetres) Fæces (average per day)	8.1600 0.7426	
Total . . . 14.6760			Total . . . 8.9026 — 5.7734		

As far as the figures obtained in the other cases could be relied upon they seemed to confirm this experiment; but I do not, for the reasons above detailed, urge their applicability.

Knowing that the local application of superheated air acts as a powerful stimulant or excitant to certain of the bodily functions (circulation, respiration) and induces more or less pronounced elevation of temperature, I was prepared to find increased metabolic activity in my cases. This expectation was, furthermore, in a measure supported by the reported cases, in which considerable adhesions and exudates have resolved under this treatment. The figures in my cases, however, do not support these preformed theories, and show conclusively that, whatever effect the hot-air treatment may have, it does not result from stimulation of general metabolism. For my own part, I am persuaded that the action is purely local, though, possibly, in a measure due to reflex nervous influences, and therefore akin to that obtained from hot fomentations, hot sand-bags, etc. The decreased output of nitrogen might be looked upon as an implication of the general metabolism. To this view, however, objection might readily be made. An increased output could have but one interpretation. On the other hand, however, the explanation may be given that the temporary retention is retention in the strictest sense. The abnormal activity of the dermal and pulmonary elimination of water, influencing unfavorably proper urinary eliminations. In a measure this view is supported by the fact that the urinary nitrogen was especially reduced, the nitrogen of the fæces being practically such as would occur under the same general conditions without baths. In point of fact, in this case the average nitrogen in the fæces was 0.6504 before and 0.7426 during the baths,—a very insignificant difference. Whereas the urinary nitrogen was about 14.3 before the baths and 10.2 during the baths,—a very marked difference. I regret that it was not possible to continue the estimations after the baths had been discontinued, for I suspect that the nitrogenous elimina-

tion would have been found greatly increased, commensurate with increased urination. To a certain degree the marked increase on the day of the fifth bath suggests the possibility of this discharge of surplus nitrogen after the system had become somewhat adapted to the new conditions, and the surplus had become excessive. It will be noted that the urine on this day increased from 575 cubic centimetres on the day before to 1045 cubic centimetres on the day in question.

The further consideration of the belief in the purely local action of the baths and the practical applicability of the treatment has been considered in Part I of this paper.

Conclusions.—The physiological effects of hot air are:

- (1) Temporarily increased circulation, respiration, and fever.
- (2) Moderate fugacious local anæsthesia.
- (3) Loss of weight, probably due to loss of water from skin and lungs.
- (4) Decreased nitrogenous output.
- (5) The effects of hot-air baths are purely local in origin.

I am indebted to Dr. George D. Morton for the accurate records and the attention to details in the administration of the baths.—C. H. F.

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